Travel Demand Models for the San Francisco Bay Area (BAYCAST-90)

Technical Summary

Charles L. Purvis, AICP
Senior Transportation Planner/Analyst

Planning Section
Metropolitan Transportation Commission
101 Eighth Street
Oakland, California 94607

June 1997

Table of Contents

List of Tables

List of Figures

I. Introduction

The purpose of this technical summary is to describe in detail the new set of travel demand models in the San Francisco Bay Area. These travel demand models were developed by staff of the Metropolitan Transportation Commission (MTC) in Oakland, California. MTC is the metropolitan planning organization (MPO) for the nine-county San Francisco Bay Area.

Travel demand models are used by transportation planners for simulating current travel conditions and for forecasting future travel patterns and conditions. Models are essentially “decision-support tools” to assist transportation planners and policy-makers in analyzing the effectiveness and efficiency of various transportation alternatives in terms of mobility, accessibility, environmental and equity impacts.

This technical summary covers the travel ***demand*** models, as opposed to the travel ***supply*** models, needed as part of a total transportation model system. Demand models are the model equations needed to predict trip frequency choice, trip destination choice, mode choice, and time-of-day choice. Supply models include the description of the zonal and network representations (transit, highway, nonmotorized) and the trip assignment methodologies needed to complement the demand models. Section III of this report is a brief summary of the networks and zone system used in MTC’s application of the BAYCAST model system.

This particular technical summary is the first of three summary reports on the new travel model system in place in the Bay Area. The two other summary reports in this series discuss model system operation *(BAYCAST Users Guide)* and aggregate model validation results.

In addition to these three summary reports, detailed technical memorandum on these new travel demand models are compiled in a set of six volumes, published at MTC between March 1995 and April 1997 (1, 2, 3, 4, 5, 6). These compilations contain detailed information on reasons and rationale for choosing the particular travel demand models summarized in this report.

The name for this new travel demand model system is BAYCAST, or more specifically BAYCAST-90 for the 1990 survey-based models. New travel model systems under development are:

- BAYCAST = Bay Area Travel Demand Model Forecasting System.
- MTCFCAST = MTC Travel Demand Model Forecasting System.
- SRFCAST = Short-Range Travel Demand Model Forecasting System.

The MTCFCAST model system was originally developed in the 1970s as a state-of-the-art disaggregate travel demand model system. MTC staff redeveloped MTCFCAST in the 1980s using updated networks and data from the 1981 MTC household travel survey.

MTCFCAST will be updated to include the best features from the old MTCFCAST and the new BAYCAST model systems.

In addition to the aggregate, trip-based modeling systems such as MTCFCAST and BAYCAST, MTC staff will also develop a fully disaggregate model system, SRFCAST, or short-range forecasting system. The SRFCAST is a "sample enumeration" model system applied at the fully disaggregate level to either households and persons from household travel surveys, or to synthetic persons and households. SRFCAST's heritage is based on model systems such as SRGP (Short Range Generalized Planning Model) and STEP (Short Range Transportation Evaluation Program) originally developed in the 1970s.

II. Software and Hardware

Hardware. MTC staff use personal microcomputers (120 Mhz and 133 Mhz pentium processors), typically equipped with 1.5 gigabytes of hard disk space and 32 MB of built-in RAM. Large data files are shared over a Novell-based local area network. Full internet and world wide web access at MTC allows for sharing of data files with external data users via HTTP (hypertext transfer protocol) and FTP (file transfer protocol).

Software. MTC uses MS-DOS programs for all applications except SAS (Statistical Analysis System). SAS for Windows is used for calibration file preparation and for estimating multiple regression and trip rate models. The MS-DOS-based programs used by MTC include:

- MINUTP (network planning package)
- ALOGIT (logit estimation package, version 3.8f), and
- FORTRAN (Microsoft's MS-DOS FORTRAN compiler).

MTC staff are developing MS-DOS based executable programs (e.g., BAYCAST.EXE and MTCFCST.EXE) for applying travel demand models and for utility operations.

The GIS system MAPINFO for Windows is used for plotting of forecasting results at the zone and superdistrict level. MAPINFO is not currently used for network editing or display purposes.

The future may include conversion to newer operating systems such as Windows 95, new network planning packages such as TP+, and newer FORTRAN and other language compilers.

BAYCAST, as a model system, is intended for application on different network planning packages, including, but not limited to: MINUTP, TRANPLAN, and EMME/2.

Old Model System. Previous versions of MTC's travel models operated on the mainframe network planning package UTPS (Urban Transportation Planning System.) MTC's microcomputers are used as "dummy terminals" to communicate with a time-share option mainframe computer in Sunnyvale. MTC staff need to master JCL (job control language), UTPS, and the TSO editor system to apply the MTC models on the mainframe system.

III. Zonal System and Networks

Zones. The new MTC zonal system is 1099 regional travel analysis zones internal to the nine-county Bay Area, and 21 external gateway zones. The 1099 regional travel analysis zones are based on 1990 census geography (tracts, block groups, blocks). MTC uses a system of 34 superdistricts for use in calibration (adjustment) and for reporting of standard results. Previous MTC model systems operated at a 290, 440, 550, 651 and 700 regional zone-levels.

Highway Network. The MTC regional MINUTP highway network includes about 31,300 one-way links. Separate "use codes" are used for mixed flow lanes, HOV 2+, HOV 3+, and restricted access to large trucks. County geographic location is a variable used in the file for reporting and plotting purposes. Functional class, area type, free flow speeds, per lane capacities and speed/flow relationships are discussed in the article by Rupinder Singh: *"Beyond the BPR Curve"* (presented at the 1995 TRB Planning Applications Conference, Seattle, Washington.)

Transit Network. The MTC regional MINUTP transit network includes 700+ transit lines for 25 transit operators. AM peak period bus speeds and auto access-to-transit speeds are based on congested highway travel times ("INET-style" transit networks). Special MTC programs (RAILFARE) are needed to add station-to-station rail fares to the MINUTP bus fare matrix. Networks are created for the AM peak period and off-peak period. Two sets of AM transit paths (walk access only; walk and auto access available) and one set of midday transit paths are used in the demand model process.

Old Model System. Previous versions of MTC's travel models operated on the mainframe network planning package UTPS (Urban Transportation Planning System.) Transit networks were coded in the old UNET (unintegrated transit/highway networks). In recent years, MTC staff used MINUTP to edit the regional highway network, at the 700 zone system level, then upload the network into UTPS HNET format.

IV. Travel Survey Database

The centerpiece data for estimating new sets of travel demand models are household travel surveys. In 1990, MTC conducted a major household travel survey of 9,359 households for their single weekday travel patterns, and an additional 1,479 households for their multiple weekday (3 or 5 consecutive weekday) travel patterns. Reference (7) contains detailed weighted and expanded results from the 1990 survey.

The 1990 household travel survey is a traditional, trip-based travel survey collecting data on trips as opposed to in-home and out-of-home activities. In contrast, the new 1996 MTC household survey is a time-use survey, collecting detailed data on in-home activities as well as out-of-home activities (as well as traditional information on trip characteristics.)

In the 1990 MTC survey, trip-based "memory jogger" cards were mailed to survey respondents after initial telephone interviews to collect standard household and person-level information. Data on trips includes information on origin location, destination location, means of transportation, time of trip start and trip completion, and vehicle occupancy.

Data from the household travel survey are extensively cleaned and analyzed before preparing model calibration files. Data from other sources, namely the Association of Bay Area Governments' land use/socio-economic zonal databases, and MTC's zone-to-zone highway and transit networks times, distances and costs, are appended to the household travel survey files as needed. Calibration files are prepared at the household level for trip generation and workers in household / auto ownership models; at the zone level for trip attraction models; at the zone-to-zone level for trip distribution models; and at the trip level for mode choice and time-of-day choice models.

<u>Old Model System.</u> Previous household travel surveys were conducted in the Bay Area in 1965 and 1981. The 1965 home interview (face-to-face) survey of over 30,000 households was used in developing traditional aggregate demand models in the 1960s and the first wave of disaggregate demand models in the 1970s. The 1981 telephone/mail survey of 6,200 households was used in updating the MTCFCAST model system in the 1980s.

V. Model System Overview

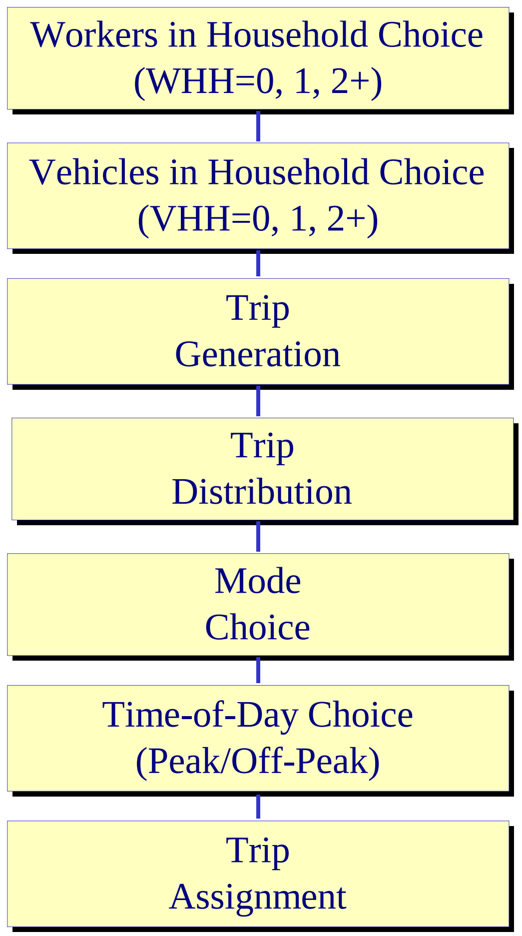
BAYCAST is designed as an advanced state-of-the-practice trip-based travel forecasting system. It is designed to be tractable, sophisticated and user-friendly.

As opposed to the typical "four-step" model, the BAYCAST modeling system includes the standard four steps of trip generation, trip distribution, mode choice and trip assignment, as well as three extra main models: workers in household, auto ownership choice, and time-of-day choice models. (See Figure 1).

Five principal trip purposes are defined for intraregional personal travel:

- Home-Based Work (HBW)
- Home-Based Shop/Other (HBSH)
- Home-Based Social/Recreation (HBSR)
- Home-Based School (HBSK)
- Non-Home-Based (NHB)

Figure 1
Bay Area Travel Demand Model Forecasting System
BAYCAST



Home-based school trips are further broken down into:

- Home-Based School: Grade School (HBGS)
- Home-Based School: High School (HBHS)
- Home-Based School: College (HBCol)

Trip-Based versus Activity-Based Travel Demand Models

Stratifying trips by trip purpose is typical of trip-based travel demand model systems. This allows the analyst to subdivide the overall travel demand market into manageable and generally well-understood submarkets: the journey-to-work, the journey-to-school, other home-based travel, and non-home-based travel. Some of these trip purposes are restricted to certain groups, i.e., only workers take journeys-to-work and only students take journeys-to-school. Other trip purposes are considered household, or family-based chores or activities such as home-based shopping and home-based social/recreation trips. Non-home-based trips are taken by anyone.

The downside of trip-based models is the independence between these trip purposes in a typical zone-based (aggregate) forecasting system such as BAYCAST. A good example of this problem is that a non-home-based trip, say, from work-to-lunch, is not linked with and has no "knowledge" or "memory" of the previous trip, say, from home-to-work, that the tripmaker took (in terms of mode used, vehicle used and available, time of travel constraints, etc.)

Alternatives to the standard trip-based modeling system are under development in other metropolitan areas (e.g., Stockholm; Portland, Oregon; Honolulu) to fully eliminate non-home-based trips and replace them with "half-tour" (e.g., home-to-work and work-to-home trip chains) or "full-tour" (home-to-home round trips) models.

(This short discussion on trip-based models with non-home-based trips, and activity-based models that exclude non-home-based trips is intended as background to future model development activities planned at MTC.)

Market Segmentation

Market segmentation is a critical feature of advanced trip-based travel demand model systems. Market segmentation is a compromise between a fully disaggregate modeling system and a fully aggregate modeling system. In a fully disaggregate modeling system, the disaggregate demand models are applied at the disaggregate, individual level. Results are only summed at the end of the process for reporting purposes. In a fully aggregate modeling system, all persons and households within a travel analysis zone are assumed to be "average" with identical characteristics in terms of average household income, average household size, average vehicles per household, average workers in the household, average students in the household, etc.

Market segmentation is useful in adapting disaggregate demand models for use in an aggregate modeling system, such as BAYCAST. Models are applied to subgroups within travel analysis zones as opposed to no subgroups. This “no subgrouping option” is also known as “naive segmentation.”

Market segmentation is particularly useful in analyzing market captivity. For example, households without automobiles are highly unlikely to drive alone to work or to drive to a transit station. Another example is that households without workers are not going to take trips from home-to-work.

The market segments used in the BAYCAST model system application include:

- household by workers in the household (WHH=0, 1, 2+);
- households by autos available in the household (AO=0, 1, 2+); and
- households by household income quartile (Income=<$25K, $25K-45K, $45K-75K, > $75K).

These three market segmentations are not used for all trip purposes and for all models (trip generation, trip distribution and mode choice).

Home-based work trips are market segmented by household income in the trip generation, trip attraction, trip distribution and mode choice models; and also by auto ownership level in the mode choice model application. Non-working households are ineligible to take home-based work trips.

Home-based shop trips are stratified by workers in household level and auto ownership level in the trip generation model; and by auto ownership level in the mode choice model. No segmentation is used in either trip attraction or trip distribution models for home-based shop.

Home-based social/recreation trips are segmented by auto ownership level in the trip generation and mode choice models. No segmentation is used in either the home-based social/recreation trip attraction or trip distribution models.

Home-based school trips are not market segmented by auto ownership level or workers in household level or income level in any of the home-based school models (generation, attraction, distribution, mode choice). The basic market segmentation for school trips is by level of school (grade school, high school, college) based on age of student (5-13, 14-17, 18-24).

Non-home-based trips are also not market segmented. Early work on separating non-home-based trips by whether or not the non-home-based trip was a work-based trip, concluded that the work-based versus non-work-based stratification was not an improvement.

Comparison of New BAYCAST Model System to Previous Versions of MTCFCAST

The following table provides a side-by-side comparison of the previous version of MTC's modeling system, MTCFCAST-80/81, with the new version of BAYCAST-90.

Characteristic	MTCFCAST-80/81	BAYCAST-90
Network Software	Mainframe UTPS	Microcomputer MINUTP
Zonal System	550 zones (expanded to 700)	1099 zones
Model Estimation Software	SAS, CS-LOGIT (mainframe)	SAS, ALOGIT (microcomputer)
Model Application Software	FORTRAN (mainframe); Assembly; UTPS	FORTRAN (MS-DOS); MINUTP
Workers in Household	Binomial Logit (non-working vs working household)	Nested Logit (non-working, single, multi-worker HH)
Auto Ownership	Multinomial Logit, LOGSUM linkages with HBWD model	Nested Logit, linked with workers in household model
Trip Purposes	4 - HBW, HBSH, HBSR, NHB Off-model: HBSch, I/X, Commercial	6 - HBW, HBSH, HBSR, HBSch, NHB, Commercial. Off-model: I/X (interregional)
Trip Generation	Hybrid (Cross-classification, regression). Motorized person trips, only.	Hybrid (Cross-classification, regression). Total person trips, including bicycle and walk.
Trip Distribution	HBW - Logit Destination Choice with LOGSUM from HBW mode choice; Others - Gravity	All purposes - gravity models based on peak highway time or blend of peak/off-peak highway time.
Mode Choice	HBW - Multinomial Logit NW - Binomial Logit	Nested Logit for all except for HB Grade School (multinomial logit)
Time-of-Day	Peaking factors derived from household travel surveys	HBW - departure time binomial logit choice model All other purposes - peaking factors derived from HH surveys
Transit Network	UNET "unintegrated"	MINUTP "integrated"
Highway Assignment	LOVs/HOVs in "layered" assignment.	LOVs/HOVs in "simultaneous" assignment.
Capacity Restraint Algorithm	Standard BPR from UTPS	Customized: CS = FFS/[1+0.2(v/c)**10]
Market Segmentation	Income tertiles through HBW distribution; auto ownership tertiles input to HBW mode choice. Primary/secondary worker segmentation for HBW trips. Non-working versus working household segmentation.	Income quartiles and auto ownership tertiles through HBW mode choice. Auto ownership tertiles in home-based non-work generation and mode choice. Non-working, single worker and multi-worker household segmentation.

The most significant improvements in the new BAYCAST-90 model system in comparison to the old MTCFCAST-80/81 model system are:

- Extensive use of nested logit choice structures in mode choice, and auto ownership/worker choice models;
- Inclusion of non-motorized trips through entire model sequence for all trip purposes;

• Sensitivity of non-work models to peak period travel times and costs;
• Full set of home-based school travel demand models;
• Full set of commercial (truck) trip generation and trip distribution models;
• New departure time choice model for home-to-work vehicle trips;
• Improved capacity restraint algorithms;
• Simultaneous as opposed to sequential, or layered, traffic assignment methodology;
• More "user-friendly" and cost-effective microcomputer-based modeling system;
• Integrated transit network coding so bus speeds are automatically adjusted based on congestion levels;
• Household income segmentation through entire work trip model sequence; and
• Auto ownership segmentation in home-based non-work mode choice models.

In terms of simplifications in the new BAYCAST system relative to the old MTCFCAST system, these issues relate to:
• Use of a gravity home-based work trip distribution model instead of a logit destination choice work trip distribution model;
• Lack of relative transit/highway accessibility variable in the auto ownership model; and,
• Exclusion of primary/secondary stratification in home-based work models.

Of these three issues, the most problematic is the exclusion of the relative transit/auto accessibility variable from the auto ownership level model. This problem can probably be amended in future work by incorporating extra variables in the existing WHHAO (workers in household / auto ownership) choice model. Accessibility variables (how many jobs are within "x" minutes by transit and auto) will be tested in future model improvements as a tractable extension to the existing WHHAO model.

The work trip distribution model is improved in terms of market segmentation (calibration by household income quartile level) but is worse in terms of sensitivity to transit travel times. The new work trip gravity distribution model is based on AM peak period drive alone travel times, only; the old work trip logit destination choice model was based on the "logsum" of the work trip mode choice model (i.e., including drive alone, carpool and transit times and costs), factored by a scaling parameter and adjusted by work trip length distribution. Logit destination choice models are difficult to estimate and calibrate, and future development of these models may not succeed. Other options for improved distribution models may include probability-weighted gravity models based on multimodal travel times (drive alone, carpool, transit, walk and bicycle).

VI. Model Descriptions

A. Workers and Vehicles in Household Nested Choice Model (WHHAO)

The MTC workers and vehicles in household model (WHHAO) is a nested logit choice model applied at the zone-of-residence level. The input to the WHHAO model application are number of households stratified by household income quartile level. Variables in this choice model include mean household income, mean household size, the share of households residing in multi-family dwelling units, the share of persons age 62-or-older, and gross population density. Coefficients for the final nested choice model, model #9W, are shown in Table 1. Detailed definition of variables in this and other models are included in Appendix Table A.1.

Data on mean household income, mean household size and gross population density is available from Association of Bay Area Governments (ABAG) forecasts. Future year data on share of multi-family units and share of persons age 62-or-more will be derived by MTC staff from 1990 decennial Census data and ABAG county-level age forecasts.

The nested structure for the WHHAO model is shown in Figure 2. The upper level nest of this model splits households into households by workers in household level (0, 1, 2+ workers per household). The lower nest further splits these households by auto ownership level (0, 1, 2+ vehicles per household).

The output from this WHHAO model is the number of households by household income quartile (4) by workers in household level (3) by auto ownership level (3) or 36 different market segments per travel analysis zone.

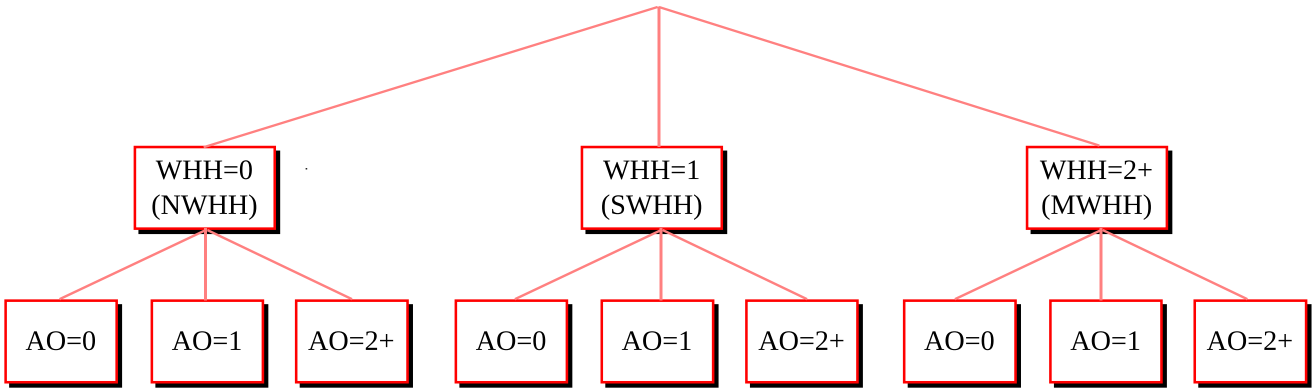
A detailed example of the calculation of the "logsum" variables used in this WHHAO model is included in a C. Purvis 10/3/95 memo included in Technical Memorandum Compilation, Volume III. The "logsum" is defined as the natural logarithm of the sum of the exponentiated utilities within the particular nest of interest.

Description of adjustments (calibration) to the utility constants, and adjustments to the coefficients by market segment, are included in the separate technical summary on calibration and aggregate validation of the BAYCAST model system.

Table 1
Worker and Vehicles in Household (WHHAO) Multinomial and Nested Choice Models - Model #9W
BAYCAST Travel Demand Model based on 1990 Bay Area Household Travel Survey, Single Day Sample

WHH=0	WHH=0	WHH=0	WHH=1	WHH=1	WHH=1	WHH=2+	WHH=2+	WHH=2+		Model #9W (MNL)		Model #9W (Nested)	
AO=0	AO=1	AO=2+	AO=0	AO=1	AO=2+	AO=0	AO=1	AO=2+	Variable	Beta	t-stat	Beta	t-stat
●									constant 1	0.9349	(1.4)	1.615	(1.4)
	●								constant 2	2.33	(3.8)	3.084	(2.6)
		●							constant 3	0.6962	(1.1)	1.679	(1.4)
			●						constant 4	0.2607	(0.4)	1.586	(1.2)
				●					constant 5	1.719	(2.9)	3.284	(2.5)
					●				constant 6	-0.4014	(0.6)	1.237	(0.9)
						●			constant 7	-1.851	(2.0)	-2.941	(2.8)
							●		constant 8	-0.3117	(0.5)	-0.7834	(1.1)
	●								Income-Leg 1	4.633E-02	(2.4)	3.956E-02	(2.1)
		●							Income-Leg 1	0.1000	(4.2)	0.0888	(3.6)
			●						Income-Leg 1	0.1093	(4.3)	0.2853	(2.4)
				●					Income-Leg 1	0.1671	(8.1)	0.3433	(3.0)
					●				Income-Leg 1	0.2139	(8.2)	0.3907	(3.3)
						●			Income-Leg 1	0.1267	(3.0)	0.9325	(1.7)
							●		Income-Leg 1	0.1729	(5.9)	0.9719	(1.8)
								●	Income-Leg 1	0.2418	(8.8)	1.0320	(1.9)
	●								Income-Leg 2	1.213E-02	(0.8)	9.989E-03	(0.6)
		●							Income-Leg 2	2.564E-02	(1.6)	2.268E-02	(1.4)
			●						Income-Leg 2	1.122E-02	(0.7)	4.776E-02	(1.4)
				●					Income-Leg 2	2.310E-02	(1.6)	5.624E-02	(1.7)
					●				Income-Leg 2	4.604E-02	(3.1)	7.682E-02	(2.4)
						●			Income-Leg 2	3.035E-02	(1.5)	0.2699	(1.6)
							●		Income-Leg 2	4.740E-02	(3.1)	0.2866	(1.7)
								●	Income-Leg 2	6.685E-02	(4.5)	0.3048	(1.8)
		●							HH Size	0.4119	(5.4)	0.3311	(3.8)
					●				HH Size	0.5893	(9.7)	0.5986	(8.9)
						●	●	●	HH Size	0.4688	(7.0)	1.3790	(2.4)
●			●			●			MFDU	0.5272	(2.8)	0.5662	(3.0)
		●			●			●	MFDU	-0.9346	(8.0)	-1.0700	(8.8)
●	●	●							SHPOP 62+	3.4230	(16.8)	4.5390	(2.9)
						●	●	●	SHPOP 62+	-2.5250	(7.3)	-12.1900	(1.7)
	●			●			●		GPOPD-Leg 1	-0.03546	(1.0)	-0.05354	(1.6)
		●			●			●	GPOPD-Leg 1	-0.05174	(1.4)	-0.07401	(2.2)
	●			●			●		GPOPD-Leg 2	-0.04837	(3.5)	-0.04987	(3.6)
		●			●			●	GPOPD-Leg 2	-0.10180	(6.4)	-0.11170	(6.9)
	●			●			●		GPOPD-Leg 3	-2.378E-02	(4.0)	-2.506E-02	(4.1)
		●			●			●	GPOPD-Leg 3	-2.380E-02	(2.7)	-2.724E-02	(2.9)
●	●	●							Theta - NWHH			0.7451	(3.0)
			●	●	●				Theta - SWHH			0.4477	(2.7)
						●	●	●	Theta - MWHH			0.1968	(1.8)
									Log Likelihood	**-2806.2**		**-2780.5**	

Figure 2
Workers and Vehicles in Household (WHHAO) - Nested Choice Model #9W



Non-Working Household Theta = 0.7451 (t=3.0)
Single-Worker Household Theta = 0.4477 (t=2.7)
Multiple Worker Household Theta = 0.1968 (t=1.8)
AO = auto ownership level
WHH = workers in household level
NWHH = non-working household
SWHH = single worker household
MWHH = multi-worker household

B. Trip Generation Models

Trip generation models include both trip production and trip attraction models. Production models are based on trips made by households, workers or students at the home end of home-based trips. Attraction models are based on trips made at the non-home end of home-based trips. Trips as defined in these trip generation models include non-motorized trips (bicycle, walk) as well as motorized modes (auto, transit).

For non-home-based trips, the same production/attraction terminology can be applied, though non-home-based generation models are essentially trip origin (production) and trip destination (attraction) models.

With the exception of the home-based school trip generation models, all of the new trip generation models are multiple regression in form. The home-based shop trip generation model, in particular, is a hybrid of a cross-classification model (stratified by workers in household level) and a multiple regression model.

Coefficients and definition of variables for all trip generation and attraction models are included in Table 2.

The independent variable in these multiple regression trip generation models are either trip rates (e.g., work trips per employed person, home-based shop attractions per retail+service+other job) or trips (e.g., total home-based social/recreation attractions, total non-home-based productions).

The home-based work and home-based school trip generation (production) models are applied to persons who are eligible to take either work or school trips, namely, workers or students. Given difficulty in estimating home-based school trip generation models, the final models are simple trip rate models: 1.314 trips per K-12 student, and 1.157 trips per college student.

Adjustment (calibration) of these trip generation models is included in the separate technical summary on calibration and aggregate validation. This document includes the calibration constants, as well as a discussion on the trip rate “caps” and “floors” that are needed in model application. In terms of aggregate validation, trip generation results are compared, at the MTC superdistrict and county level, to census-based “observed home-based work trips;” or 1990 survey-based observed non-work trips.

Table 2
Summary of BAYCAST Trip Generation Models

Home-Based Work Trip Generation	
Generation	HBWG/EMPRES = 1.0525 + 1.632E-02 * HHINC - 2.190E-04 * HHINC^2 + 8.50E-07 * HHINC^3
Attraction	HBWA/TOTEMP = 0.7782 + 0.5661 * WRKR/JOB10 - 0.1289 * WRKR/JOB^2 + 0.00873 * WRKR/JOB10^3 - 0.03928 * GEMPG10 + 0.3396 * CORE
	Where: HHINC = Household Income in Thousands of 1989 Constant Dollars WRKR/JOB10 = Worker/Job Ratio Decile code GEMPDG10 = Gross Employment Density, of Work, Decile Code CORE = Regional Core Zones Dummy
Market Segmentation	Household Income Quartile (Generation and Attraction)
Home-Based Shop/Other Trip Generation	
Generation	HBSHG/ZWHH = 0.3141 + 0.4709 * PHH + 0.4034 * VHH + 0.02052 * HHINC - 0.000131 * HHINC^2 HBSHG/SWHH = -0.4419 + 0.7299 * PHH + 0.2279 * VHH + 0.005123 * HHINC HBSHG/MWHH = -0.4288 + 0.5921 * PHH + 0.09071 * VHH + 0.009143 * HHINC - 6.054E-5 * HHINC^2
Attraction	HBSHA/RSOEMP = 0.1363 - 0.04506 * LogNEMPD + 1.6169 * TOTHHRT1 + 0.7365 * TOTHHRT2 + 2.9835 * RETEMPRT
	Where: PHH = Average Household Size (Persons Per Household) VHH = Average Vehicles per Household HHINC = Household Income in Thousands of 1989 Constant Dollars LogNEMPD = Natural Log of RSOEMP / Commercial/Industrial Acres TOTHHRT1 = Ratio of Total Households to RSOEMP, where ratio is less than 1.0 TOTHHRT2 = Ratio of Total Households to RSOEMP, where ratio is greater than 1.0 RETEMPRT = Ratio of Retail to RSO Employment RSOEMP = Retail + Service + Other Employment
Market Segmentation	Workers in Household (3) by Household Income Quartile by Auto Ownership Level (3) (Generation Only)
Non-Home-Based Trip Generation	
Generation	NHBG = 0.798 * OTHEMP + 2.984 * RETEMP + 0.916 * SEREMP + 0.707 * TOTHH
Attraction	NHBA = 0.636 * OTHEMP + 3.194 * RETEMP + 0.730 * SEREMP + 0.803 * TOTHH
	Where: OTHEMP = Other Employment RETEMP = Retail Employment SEREMP = Service Employment TOTHH = Total Households
Market Segmentation	None

Table 2 (Continued)
Summary of BAYCAST Trip Generation Models

Home-Based Social/Recreation Trip Generation

Generation	HBSRG/HH = 0.4102 + 0.1176 * PHH + 0.002849 * HHINC - 0.4632 * WHHRATE + 0.1487 * VHH - 0.08118 * ZVHH - 0.1049 * ZWHH
Attraction	HBSRA = 0.8674 * RETEMP + 0.1606 * SEREMP + 0.5216 * TOTHH
	Where: PHH = Average Household Size (Persons Per Household) VHH = Average Vehicles per Household HHINC = Household Income in Thousands of 1989 Constant Dollars WHHRate = Share of Persons in Household who Work (EMPRES/HHPOP) ZVHH = Zero Vehicle Household Dummy ZWHH = Zero Worker Household Dummy RETEMP = Retail Employment SEREMP = Service Employment TOTHH = Total Households
Market Segmentation	Workers in Household (3) by Household Income Quartile by Auto Ownership Level (3) (Generation Only)

Home-Based School Trip Generation

Generation	HBGSP = POP0513 * 0.923 * 1.314 HBHSP = POP1417 * 0.943 * 1.314 HBColP = POP1824 * <PCTENR_C> * 1.157
Attraction	HBGSA = HBGSP HBHSA = HSENROLL * 1.314 HBColA = COLL_FTE * 1.157
	Where: HBGSP, HBGSA = Home-Based Grade School Productions and Attractions HBHSP, HBHSA = Home-Based High School Productions and Attractions HBColP, HBColA = Home-Based College Productions and Attractions POP0513 = Number of Persons age 5-13 POP1417 = Number of Persons age 14-17 POP1824 = Number of Persons age 18-24 0.923, 0.943 = Percent of persons enrolled by age (1990 Census PUMS) 1.314, 1.157 = Trips per student (estimated from 1990 Survey) PCTENR_C = Percent of 18-24 year olds, enrolled in college, by County (PUMS) HSENROLL = High School Enrollment COLL_FTE = College Full Time Equivalent Enrollment
Market Segmentation	None

C. Trip Distribution Models

Gravity models are the most common form of trip distribution models. Other forms include logit destination choice models (earlier Bay Area models) and intervening opportunities models (Chicago models). Fratar, or growth factor models, are also used for short-term extrapolation of base year trip tables. All of the new Bay Area trip distribution models are gravity in form.

The final set of friction factors used in the BAYCAST gravity trip distribution models are included in Table 3. Essentially these are “lookup” tables to substitute friction values for travel time.

Travel time as used in the BAYCAST gravity trip distribution model is either AM peak period door-to-door drive alone travel time; or a blend of AM peak period and off-peak period door-to-door drive alone travel time.

In the case of home-based work and home-based school trips, only AM peak period travel times are used. For home-based shop, home-based social/recreation and non-home-based trips, a “blended” travel time based on 32.4% peak and 67.6% off-peak travel time is used. These blending shares are based on time-of-day information by trip purpose from the 1990 MTC household travel survey, as follows:

Time Period	HBW	HBSH + HBSR	HBSK	NHB	HBW + HBSK	HBSH, HBSR, NHB	TOTAL
AM Peak	1645741 36.9%	656493 10.8%	738907 44.2%	325277 6.9%	2384648 38.9%	981770 9.1%	3366418 19.9%
PM Peak	1345441 30.2%	1516593 24.9%	179723 10.8%	1000769 21.2%	1525164 24.9%	2517362 23.3%	4042526 23.9%
Total	4461255 100.0%	6096871 100.0%	1670741 100.0%	4715609 100.0%	6131996 100.0%	10812480 100.0%	16944476 100.0%
PEAK (AM+PM)	2991182 67.0%	2173086 35.6%	918630 55.0%	1326046 28.1%	3909812 63.8%	3499132 32.4%	7408944 43.7%
OFFPEAK	1470073 33.0%	3923785 64.4%	752111 45.0%	3389563 71.9%	2222184 36.2%	7313348 67.6%	9535532 56.3%

AM Peak Period = 6:00-9:00 AM (3 hours)
PM Peak Period = 3:30-6:30 PM (3 hours)
Off-Peak = 9:00 AM - 3:30 PM; 6:30 PM - 6:00 AM (18 hours)

The home-based work trip distribution model is actually four sets of friction factors applied to HBW trip ends stratified by household income quartile level. Data from the 1990 Census-based “observed” home-based work trip tables were used in calibrating these friction factors.

In addition to friction factors, socio-economic adjustment factors (k-factors) are used in calibrating and validating trip distribution models. These k-factors, along with model validation results, including average trip lengths, regional trip length frequency distributions, and modeled versus observed county-to-county and superdistrict-to-superdistrict trip tables, are included in the separate technical summary on calibration and aggregate validation.

For information purposes, the regional results of the BAYCAST model validation process through trip distribution is represented below:

	Total Person Trips	Average Distance	Average Time	Total Distance	Total Time
Home-Based Work					
Income Quartile 1	534,639	9.47	18.79	5,063,031	10,045,867
Income Quartile 2	1,124,801	11.43	21.28	12,856,475	23,935,765
Income Quartile 3	1,620,069	12.91	23.15	20,915,091	37,504,597
Income Quartile 4	1,284,902	13.31	23.88	17,102,046	30,683,460
Total, Home-Based Work	4,564,411	12.25	22.38	55,914,035	102,151,518
Home-Based Shop/Other	4,259,935	5.73	11.75	24,409,428	50,054,236
Home-Based Social/Recreation	1,910,361	7.39	13.69	14,117,568	26,152,842
Home-Based School					
Home-Based Grade School	842,871	3.20	8.11	2,697,187	6,835,684
Home-Based High School	345,542	4.41	10.00	1,523,840	3,455,420
Home-Based College	438,063	8.81	17.93	3,859,335	7,854,470
Total, Home-Based School	1,626,476	4.97	11.16	8,083,586	18,151,472
Non-Home-Based	4,716,990	6.11	12.82	28,820,809	60,471,812
Total	17,078,173	7.69	15.05	131,345,425	256,981,880

Home-based work trips comprise 26.7 percent of all trips and yet 42.6 percent of all person miles of travel. Non-home-based trips comprise the largest trip purpose share, at 27.6 percent of all trips in the Bay Area, yet are just 21.9 percent of all person miles of travel.

Home-based shop trips are 24.9 percent of all trips and 18.6 percent of all person miles of travel. Home-based social/recreation trips are 11.2 percent of all trips and 10.7 percent of all person miles of travel.

Home-based school trips are the shortest trips with an average trip length of 4.97 miles. School trips are 9.5 percent of Bay Area trips, and 6.2 percent of Bay Area person miles of travel.

Table 3 (continued)
Final Friction Factors for BAYCAST Trip Distribution Models

Travel Time	Home - Based Work IncQ1	IncQ2	IncQ3	IncQ4	HBased Shop/Oth	HBased Soc/Rec	HBased Grade Sch	HBased High Sch	HBased College	NonHome Based
1	400000	350000	320000	350000	500000	250000	999999	999999	999999	999999
2	300000	250000	215000	250000	250000	200000	500000	999999	999999	999998
3	220000	125000	100000	138000	143000	202000	200000	300000	175000	290073
4	80000	53000	45000	53000	55000	108000	40000	100000	125000	143547
5	45000	30000	29000	28000	33000	50000	23000	80000	50000	85960
6	35000	27500	23000	24300	27500	32200	13500	60000	35000	44936
7	25000	20000	17500	18400	17000	20500	7500	40000	22500	33931
8	20000	16500	15000	14500	10000	13100	4000	20000	16500	21498
9	17500	13500	12500	12600	7500	12200	2000	10000	12000	17186
10	14500	12000	10400	11000	4000	7250	1500	7500	10000	13092
11	13000	10700	9200	8900	3360	6222	1000	4000	6000	10838
12	9700	8600	7500	7600	2500	5495	750	2500	5000	6104
13	7400	6800	6400	6200	1700	3800	500	1500	4000	5174
14	6000	5900	5700	5400	1300	2500	300	1100	3000	3396
15	5000	5000	5000	5000	900	2200	200	950	2000	2453
16	4800	4700	4600	4200	800	1671	150	800	1800	2338
17	4000	4000	3900	3800	690	1341	125	675	1600	1642
18	3700	3500	3600	3500	475	1102	75	550	1400	1232
19	3400	3100	3200	3100	450	955	50	425	1200	1125
20	2700	2800	3000	2800	350	770	40	325	1000	1101
21	2600	2600	2600	2500	300	600	30	250	875	855
22	2300	2300	2300	2250	200	500	25	220	750	665
23	1800	2100	2100	2000	150	440	24	175	650	618
24	1700	1900	1900	1800	125	390	23	150	550	518
25	1400	1700	1700	1650	115	350	22	110	475	414
26	1300	1400	1500	1500	100	270	21	90	440	387
27	1050	1200	1300	1350	90	240	20	75	360	359
28	900	1100	1200	1200	75	215	19	60	320	287
29	800	1000	1100	1100	55	190	18	50	280	255
30	725	850	975	950	53	170	17	40	240	233
31	650	750	900	850	50	150	16	30	200	198
32	575	700	800	800	47	133	15	25	170	180
33	500	650	700	725	43	120	14	19	140	172
34	450	600	600	650	40	110	13	17	120	153
35	400	550	550	575	35	100	12	16	100	137
36	360	500	500	525	34	90	11	15	90	130
37	335	450	450	475	33	80	10	14	82	115
38	325	400	400	450	31	75	9	13	74	104
39	300	350	375	425	23	63	8	12	66	95
40	275	325	350	400	22	60	7	11	58	85
41	240	300	325	350	21	57	6	10	50	77
42	220	260	295	325	20	54	5	9	43	71
43	200	230	275	300	17	52	4	8	38	63
44	180	210	250	275	15	50	3	7	33	59
45	160	195	225	250	13	47	2	6	28	54

Table 3 (continued)
Final Friction Factors for BAYCAST Trip Distribution Models

Travel Time	Home - Based Work IncQ1	IncQ2	IncQ3	IncQ4	HBased Shop/Oth	HBased Soc/Rec	HBased Grade Sch	HBased High Sch	HBased College	NonHome Based
46	140	185	200	225	10	44	2	5	25	48
47	130	175	185	200	9	41	2	4	23	43
48	120	170	170	190	8	38	2	3	21	41
49	110	155	160	170	7	39	2	2	20	38
50	100	140	150	160	6	36	2	1	19	36
51	95	125	140	150	6	33	1	---	18	34
52	90	110	130	140	6	30	1	---	17	32
53	86	100	120	130	6	28	1	---	16	30
54	82	90	110	120	5	26	1	---	15	28
55	78	85	100	110	5	24	1	---	14	27
56	74	80	95	100	5	26	1	---	13	25
57	70	77	90	90	4	23	1	---	12	24
58	66	74	85	85	4	20	1	---	12	22
59	62	71	80	82	4	18	1	---	11	21
60	58	68	75	77	4	17	1	---	11	21
61	54	63	70	72	4	16	1	---	10	21
62	50	58	65	67	3	15	1	---	10	20
63	46	53	60	63	3	14	1	---	9	19
64	42	48	56	59	3	13	1	---	9	18
65	38	43	51	56	3	12	1	---	8	17
66	34	38	47	52	3	11	1	---	8	16
67	31	33	43	48	2	10	1	---	7	16
68	28	30	39	44	2	9	1	---	7	15
69	26	28	35	41	2	8	---	---	6	13
70	24	26	31	37	1	7	---	---	6	12
71	22	24	28	33	1	6	---	---	5	11
72	20	23	25	29	1	6	---	---	5	10
73	18	22	22	25	1	6	---	---	5	9
74	16	21	20	21	1	5	---	---	4	8
75	14	20	19	18	1	5	---	---	4	8
76	13	19	18	17	1	5	---	---	4	7
77	12	18	16	16	1	5	---	---	3	7
78	11	17	15	15	1	4	---	---	3	6
79	10	15	13	14	1	4	---	---	3	6
80	9	13	12	13	1	4	---	---	3	6
81	9	11	10	12	---	4	---	---	3	6
82	9	10	9	11	---	4	---	---	3	6
83	8	9	8	10	---	4	---	---	2	5
84	8	8	8	9	---	4	---	---	2	5
85	8	8	8	8	---	4	---	---	2	4
86	7	7	8	8	---	---	---	---	2	4
87	7	7	7	7	---	---	---	---	2	4
88	7	7	7	7	---	---	---	---	2	3
89	6	7	7	7	---	---	---	---	1	3
90	6	6	6	6	---	---	---	---	1	2

Table 3 (continued)
Final Friction Factors for BAYCAST Trip Distribution Models

Travel	Home - Based Work				HBased	HBased	HBased	HBased	HBased	NonHome
Time	IncQ1	IncQ2	IncQ3	IncQ4	Shop/Oth	Soc/Rec	Grade Sch	High Sch	College	Based
91	6	6	6	6	---	---	---	---	1	2
92	5	6	6	6	---	---	---	---	1	---
93	5	6	5	5	---	---	---	---	1	---
94	4	5	5	5	---	---	---	---	1	---
95	4	5	4	5	---	---	---	---	1	---
96	3	4	4	4	---	---	---	---	1	---
97	3	4	4	4	---	---	---	---	1	---
98	2	4	4	3	---	---	---	---	1	---
99	2	3	4	3	---	---	---	---	---	---
100	2	3	3	3	---	---	---	---	---	---
105	1	2	2	3	---	---	---	---	---	---
110	1	2	2	2	---	---	---	---	---	---
115	1	1	1	1	---	---	---	---	---	---
120	1	1	1	1	---	---	---	---	---	---
125	1	1	1	1	---	---	---	---	---	---

D. Mode Choice Models

The standard form for mode choice models is the logit choice model. Logit models were introduced by researchers in the late 1960s and entered practice in the Bay Area and elsewhere in the early 1970s. Prior to logit models, the most common form of mode choice model was the "diversion curve" model used to split trips between auto and transit modes.

Various options in logit models are binomial logit (two alternatives); multinomial logit (multiple alternatives, typically 3+); sequential-nested logit (mechanically feeding the logsum from a lower level logit choice model to an upper level choice model); and the simultaneous-nested logit model ("full information" from the lower nest affecting the scaling, or nesting parameter to the upper nest).

Model development in the 1970s was limited to binomial, multinomial and sequential-nested logit choice models. Simultaneous-nested logit procedures were developed in the late 1970s and made available in commercial software (e.g., ALOGIT, LIMDEP) in the late 1980s and early 1990s.

Of the seven mode choice models included in the BAYCAST model set, six are simultaneous-nested logit choice model (hereafter, "nested logit choice") and one, the home-based grade school mode choice model, is multinomial logit. The overall structure of these seven mode choice models is shown in Figure 3. All of the detailed technical memorandum discussing mode choice model development are in the Technical Memorandum Compilation Volume VI.

One key indicator in reviewing mode choice models is the "value of time" (Table 4). This value of time concept is useful in understanding tradeoffs between travel time (typically in-vehicle travel time) and trip cost. The rule of thumb for work trips is that the value of time is 25 to 50 percent of the average wage rate for the area. Given an average wage rate of $20.82 per hour for the Bay Area, the expected work trip value of time ranges from $5.20 to $10.41 per hour. The final nested work trip mode choice model yields an average value of time of $9.65 per hour, or 46.4 percent of the average Bay Area wage rate.

The rules of thumb for non-work trip values of time are not as well agreed upon as the value of time for work trips. The general feeling is that non-work value of time should be some fraction of work trip value of time. The values of time for BAYCAST non-work mode choice models range from a high of $6.58 per hour for home-based shop trips (68 percent of the work trip value of time) to a low of $0.23 per hour for home-based high school trips (2.4 percent of the work trip value of time). All of these values of time for non-work trips are fairly reasonable and well within acceptable practice for analyzing value of time.

An important characteristic of most BAYCAST mode choice models (with the exception of the three home-based school mode choice models) is that both AM peak period and off-peak period travel times and trip costs are used in the model application. In previous versions of MTC model systems, home-based work trips were only sensitive to peak period travel times and costs; and non-work trips were only sensitive to off-peak times and costs. This improvement in the model system means that mode choice for these trip purposes is sensitive to changes in both the peak and off-peak period, as opposed to just one or the other.

All mode choice models incorporate non-motorized alternatives: bicycle and walk-only. Travel times for bicycle and walk are based on a "non-motorized network" based on the standard regional highway network, excluding freeway facilities where bicycles and pedestrians are not allowed (and including freeway facilities where bicycles and pedestrians are allowed!) Uniform speeds of 3 miles per hour for pedestrians and 12 miles per hour for bicyclists are used to convert non-motorized distance into travel time.

The <u>home-based work mode choice model</u> is the only two-level nested choice model in the BAYCAST model set. Trips are first split into motorized modes, bicycle and walk-only modes. Motorized trips are then split into drive alone, shared ride 2, shared ride 3+ and transit. Lastly, transit trips are split into transit with walk access versus transit with auto access. Market segmentation into the HBW mode choice model is zone-to-zone trips by AO level (3) by household income quartile level (4). Where the auto ownership is zero, work trips are prohibited from taking the drive alone or transit-auto access modes. Coefficients for the final nested HBW mode choice model (Model #97) are shown in Table 5.1. Definitions for these variables are included in Appendix Table A.1.

As is typical with mode choice models, the BAYCAST home-based work mode choice model include variables about tripmaker demographics (auto ownership, income, household size, workers in the household); trip characteristics (travel time and trip cost); and neighborhood characteristics (employment density; "dummy" variables to represent high bicycle commute shares in Stanford, Palo Alto and Berkeley; and "dummy" variables for regional "core" zones in the San Francisco financial district).

Modal constants are estimated for six of the seven modal utilities in the HBW mode choice model. These modal constants are then calibrated (adjusted) on a district-to-district interchange basis so that model predicted trips reasonable match observed trips by mode. These changes, or "deltas" to the modal constants are included in the separate technical summary on calibration and aggregate validation.

The coefficients for the final <u>home-based shop/other</u> mode choice model (model #73W-2) are shown in Table 5.2. Both the home-based shop and home-based social/recreation mode choice models include six alternatives (drive alone, shared ride 2, shared ride 3+, transit, bicycle, walk) and one nest (either motorized or group modes). The nest for the HBSH model splits motorized trips from bicycle and walk trips in the upper nest; and drive alone, shared ride 2, shared ride 3+ and transit in the lower nest. As with the HBW model, trips where the auto ownership level is zero are prohibited from using drive alone or auto access to transit. The home-based shop mode choice model is the only model where a total travel time variable is used. All other models were successful in terms of separating in-vehicle travel time (IVTT) from out-of-vehicle travel time (transit wait times, walk times).

All non-work trip mode choice models use a natural logarithm transformation of trip cost. This was done since the straight, or linear versions of trip cost yielded either unacceptable coefficients for cost or for the calculated value of time. Value of time is calculated using the average trip cost by trip purpose (see Table 4).

Coefficients for the final home-based social/recreation mode choice model (nested model #35) are summarized in Table 5.3. The nest for the HBSR model is a "group nest." The upper nest splits drive alone, group modes, bicycle and walk trips. The lower nest splits shared ride 2, shared ride 3+ and transit trips. The ratio of the out-of-vehicle to in-vehicle travel time coefficients is 2.48 (-0.06806 / -0.02745) which is consistent with a priori expectations. The value of time for home-based social/recreation trips, at $0.78 per hour, is on the low side but is fairly reasonable relative to other trip purposes.

The coefficients for the final nested non-home-based mode choice model, model #14W-2 are shown in Table 5.4. This model includes five alternatives (driver, passenger, transit, bicycle walk) and one nest (motorized trips). The upper nest for the NHB mode choice model splits trips into motorized, bicycle and walk modes. The lower nest splits motorized trips into vehicle driver, vehicle passenger and transit modes. The ratio of the wait time to in-vehicle time coefficients is a very respectable 2.42 (-0.07836 / -0.03232). The ratio of the walk time to in-vehicle time coefficients is 2.35 (-0.07583 / -0.03232). Value of time for non-home-based trips is a reasonable $1.08 per hour. Given that traditional non-home-based trips are not linked with the home characteristics of the trip maker, typical demographic variables such as household income and household size are excluded from this model.

Coefficients for the final multinomial logit choice model for home-based grade school trips (model #21W) are included in Table 5.5. This multinomial logit model has four alternatives: vehicle passenger, transit, bicycle and walk. Grade school students are too young to drive to school, so the vehicle driver alternative is excluded in this model. The ratio of out-of-vehicle to in-vehicle travel time coefficients is on the low side, at 1.09 (-0.06384 / -0.05855). The value of time for home-based grade school trips is also (reasonably) low at $0.36 per hour.

The coefficients for the final nested home-based high school mode choice model (model #18W-3) are included in Table 5.6. There are five alternatives in this model and the home-based college model: vehicle driver, vehicle passenger, transit, bicycle and walk. The upper nest in the home-based high school model splits trips into vehicle driver, "group modes," bicycle and walk. The lower nest splits group modes into vehicle passenger and transit passenger modes. The ratio of out-of-vehicle to in-vehicle time coefficients is also on the low side, at 1.07 (-0.03463 / -0.03228). The value of time is the lowest of all mode choice models, at $0.23 per hour.

The final mode choice model, the home-based college mode choice model (model #28W-2) is documented in Table 5.7. The upper level nest in this model splits motorized modes, bicycle and walk trips. The lower level splits motorized trips into vehicle driver, vehicle passenger and transit passenger modes. To represent the high bike-to-college share to Stanford and Berkeley, "dummy" variables are used to represent residential areas in Stanford, Berkeley and Palo Alto. A separate bicycle time coefficient is estimated in the home-based college model; in comparison, all other models include bicycle travel time as "in-vehicle" travel time. The out-of-vehicle to in-vehicle coefficient ratio is on the low side, at 1.44 (-0.03923 / -0.02731). Value of time is higher for college trips than for grade school or high school trips, at $0.67 per hour.

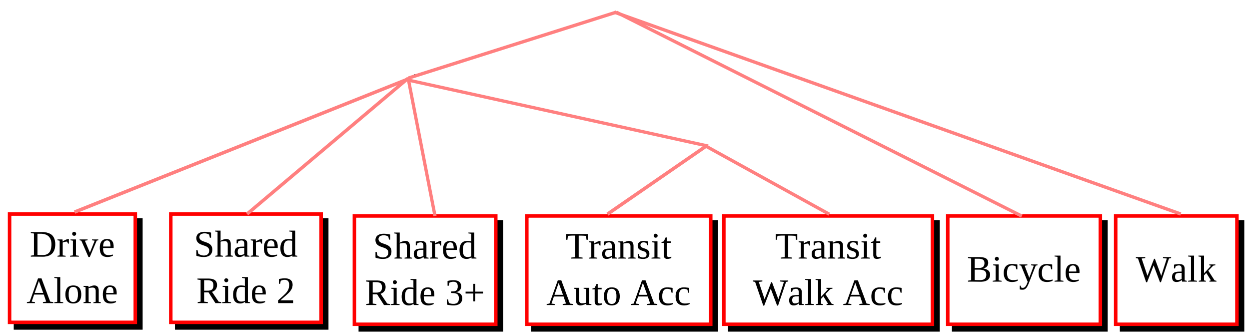
The mode choice model applications are designed for preparing transit and auto person trip tables for trip assignment. Up to three transit trip tables are output per trip purpose (AM peak auto access, AM peak walk access, midday walk access) for directly assigning transit trips to the appropriate transit path. Auto person trips need to be peak-hour factored using the home-to-work departure time model or peaking factors derived from household travel surveys. Auto person trips also have to be divided by appropriate vehicle occupancy levels to convert auto person trips into vehicle driver trips.

Certain travel modes, namely, vehicle passenger trips, bicycle and walk trips, will not normally be assigned to networks. They will be used in conjunction with other evaluation programs to account for person miles of travel by these modes, but there will not be an ongoing need for assigning these particular trips.

(Text continues on page 36.)

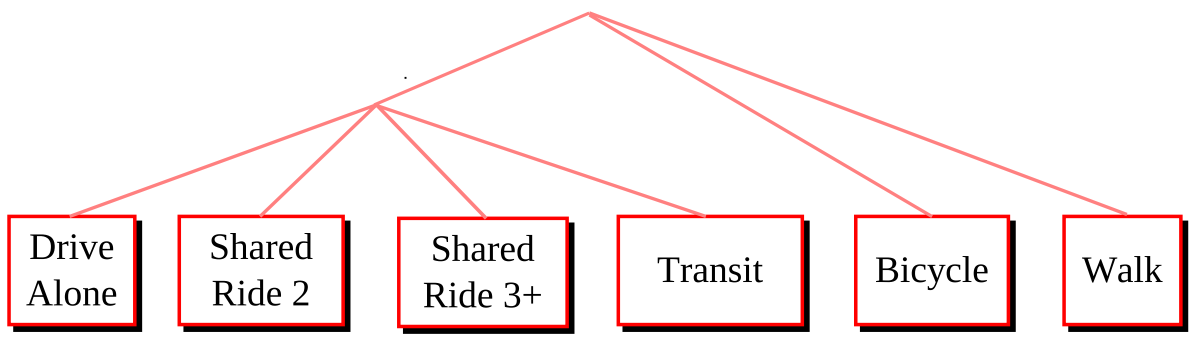
Figure 3

Home-Based Work Mode Choice - Nested Model #97



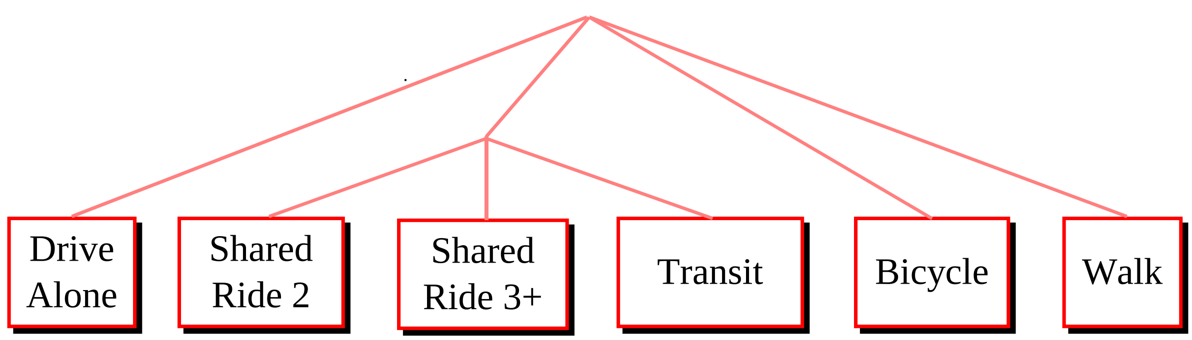
Motorized Theta = 0.9208 (t=0.6)
Transit Theta = 0.7194 (t=2.2)

Home-Based Shop/Other Mode Choice - Nested Model #2



Motorized Theta = 0.4847 (t=4.9)

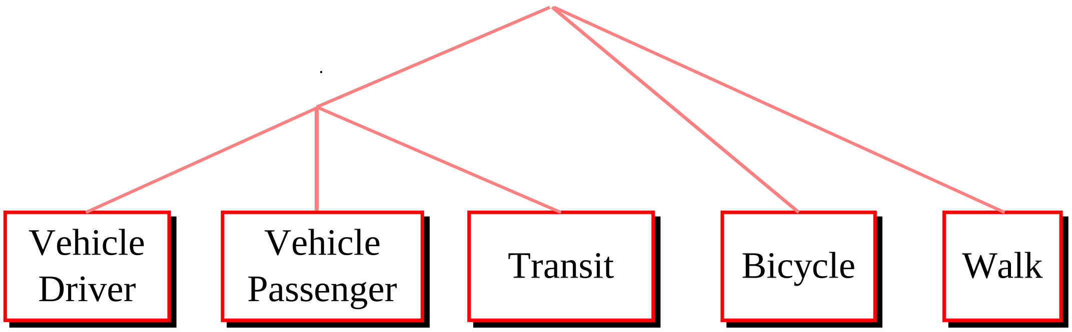
Home-Based Social/Recreation Mode Choice - Nested Model #35



Group Mode Theta = 0.6271 (t=3.2)

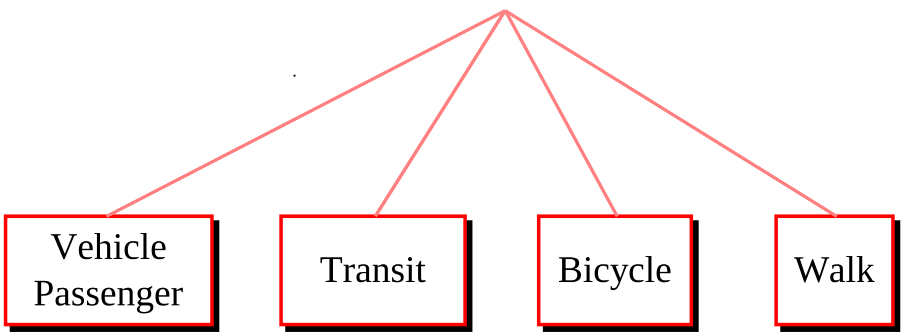
Figure 3 (continued)

<u>Non-Home-Based Mode Choice - Nested Model #14W-2</u>

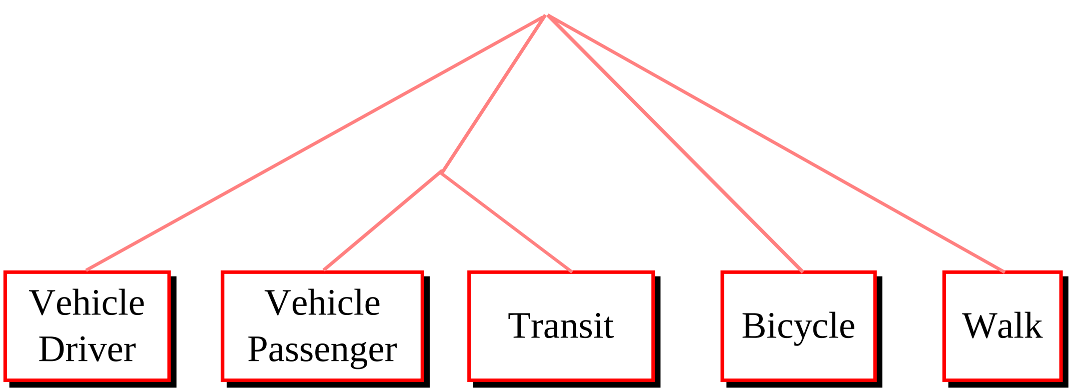


Motorized Theta = 0.9144 (t=1.0)

<u>Home-Based School: Grade School Mode Choice - Model #21W</u>



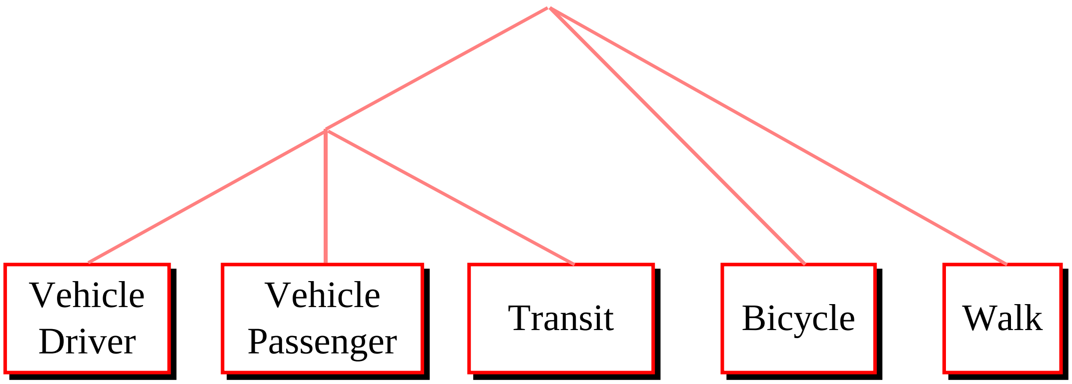
<u>Home-Based School: High School Mode Choice - Model #18W-Nest 3</u>



Group Mode Theta = 0.2583 (t=5.5)

Figure 3 (continued)

<u>Home-Based School: College Mode Choice - Model #28W - Nest 2</u>



Motorized Mode Theta = 0.5302 (t=2.6)

Table 4
Value of Time Estimates by Trip Purpose
Based on Motorized In-Vehicle and Cost Coefficients
(1990 Constant Dollars per Hour)

Trip Purpose	In-Vehicle Coefficient	Cost or LnCost Coefficient	**Value of Time**	Share of Wage Rate	Model Source
Home-Based Work	-0.03326	-0.002067	**$9.65**	46.4%	Nested Model #97
Home-Based Shop	-0.05815	-0.2262	**$6.58**	31.6%	Nested Model 73W-2
Home-Based Social/Rec	-0.02745	-1.16	**$0.79**	3.8%	Nested Model #35
Home-Based Grade School	-0.05855	-1.93	**$0.36**	1.7%	Model #21W
Home-Based High School	-0.03228	-2.034	**$0.23**	1.1%	Nested Model #18W-3
Home-Based College	-0.02731	-0.692	**$0.67**	3.2%	Nested Model #28W-2
Non-Home-Based	-0.03232	-0.9862	**$1.08**	5.2%	Nested Model #14W-2

Notes:
1) In-Vehicle coefficient for the HBSH model is total travel time.
2) Cost coefficients for all non-work models are for natural log of trip cost.
3) Value of time for HBW trips is IVTT/COST * 0.60.
4) Value of time for HBSH trips is TTT/LnCost * 0.60 * 42.65. The 42.65 is average trip cost.
5) Value of time for HBSR trips is IVTT/LnCost * 0.60 * 55.33. The 55.33 is average trip cost.
6) Value of time for HBGS trips is IVTT/LnCOST * 0.60 * 19.57. The 19.57 is average trip cost.
7) Value of time for HBHS trips is IVTT/LnCost * 0.60 * 23.9. The 23.9 is average trip cost.
8) Value of time for HBCol trips is IVTT/LnCost * 0.60 * 28.1. The 28.1 is average trip cost.
9) Value of time for NHB trips is IVTT/LnCost * 0.60 * 54.92. The 54.92 is average trip cost.
10) The Bay Area average wage rate is $20.82 per hour.

Table 5.1
Final Multinomial and Nested Home-Based Work Mode Choice Models
Multinomial Model #99W and Nested Model #97

Utility							Variable	Model #99W		NestModel #97	
DA	SR2	SR3+	TR-A	TR-W	Bike	Walk	Name	Coeff.	T-Stat	Coeff.	T-Stat
●							Constant	-6.305	(9.1)	-9.234	(4.0)
	●						Constant	-9.177	(12.8)	-13.310	(4.1)
		●					Constant	-9.524	(13.4)	-13.780	(4.1)
			●				Constant	-8.802	(12.4)	-12.250	(4.6)
				●			Constant	-7.164	(11.2)	-10.380	(4.1)
					●		Constant	-8.63	(13.6)	-8.268	(12.4)
					●		LnEmpDi	0.3474	(2.4)	0.3243	(2.2)
			●	●			LnEmpDj	0.3834	(6.7)	0.5461	(3.3)
●							Veh/HH	0.8841	(10.1)	1.2240	(4.5)
	●						Veh/HH	0.6489	(7.2)	0.9023	(4.2)
		●					Veh/HH	0.6754	(7.1)	0.9357	(4.2)
	●						Single VHH	0.5871	(4.1)	0.8370	(2.9)
			●				Veh/HH	0.5109	(3.5)	0.5697	(3.1)
				●			No VHH	0.4731	(2.1)	0.5501	(1.4)
●							Wrkr/HH	-0.1781	(2.9)	-0.2454	(2.3)
	●						Multi-Wrkr/HH	0.6655	(4.6)	-0.9297	(3.0)
●							Pers/HH	-0.2202	(7.1)	-0.3099	(3.6)
●							IncomeLeg1	4.077E-05	(2.3)	5.878E-05	(2.0)
	●	●					IncomeLeg1	3.388E-05	(1.8)	5.049E-05	(1.7)
●	●	●	●	●	●		IVTT	-0.02683	(5.3)	-0.03326	(4.3)
			●	●			Wait	-0.04180	(4.0)	-0.05233	(3.1)
●	●	●	●	●			Walk	-0.05776	(2.7)	-0.09305	(2.2)
●	●	●	●	●			Cost	-0.001468	(3.2)	-0.002067	(2.6)
					●		Stanfordj	2.033	(2.9)	2.09	(3.0)
					●		PaloAltoj	1.626	(2.4)	1.584	(2.3)
					●		Berkeleyj	1.062	(1.6)	1.01	(1.5)
●							Corej	-0.7605	(3.7)	-1.086	(2.7)
			●				Corej	1.004	(3.5)	1.147	(3.3)
						●	LnWalkTime	-2.174	(14.0)	-2.137	(13.5)
						●	LnEmpDj	0.1418	(2.0)	0.1418	(2.1)
			●	●			Theta (Transit)			0.7194	(2.2)
●	●	●	●	●			Theta (Motor)			0.9208	(0.6)
Value of Time (IVTT/Cost * .60)								**$10.97**		**$9.65**	
Ratio of Wait/IVTT								**1.56**		**1.57**	
Ratio of Walk/IVTT								**2.15**		**2.80**	

Note: Variable definitions are included in Table A.1.

Table 5.2
Final Nested Home-Based Shop/Other Mode Choice Model
Nested Model #73W - Nest 2

Utility						Variable	Nested Model #73W-2	
DA	SR2	SR3+	Trans	Bike	Walk	Name	Coeff.	T-Stat
●						Constant	0.5495	(0.7)
	●					Constant	-0.3612	(0.5)
		●				Constant	-2.4860	(3.4)
			●			Constant	-1.7470	(2.4)
				●		Constant	-3.9280	(13.5)
	●					LnPHH	0.6635	(7.8)
		●				LnPHH	2.2360	(17.9)
			●			Veh/HH	-0.3352	(4.0)
●						LnIncome	0.1952	(2.7)
	●					LnIncome	0.1118	(1.6)
●	●	●	●	●	●	Time (Total)	-0.05815	(13.5)
●	●	●	●			LnCost	-0.2262	(1.4)
			●			Corej	2.3750	(6.0)
●	●	●				LnAreaDeni	-0.4701	(3.8)
				●		Stanfordj	2.488	(2.5)
				●		Berkeleyj	1.630	(3.0)
				●		PaloAltoj	1.377	(1.7)
●						Zero WHH	-0.2273	(2.0)
			●			Zero VHH	3.2910	(10.8)
					●	Zero VHH	1.7350	(6.6)
●	●	●	●			Theta (Motor)	0.4847	(4.9)
Value of Time (Time/Cost * .60 * 42.65)							**$6.58**	

Note: Variable definitions are included in Table A.1.

Table 5.3
Final Nested Home-Based Social/Recreation Mode Choice Model
Nested Model #35

Utility						Variable	NestModel #35	
DA	SR2	SR3+	Trans	Bike	Walk	Name	Coeff.	T-Stat
●						Constant	1.295	(2.0)
	●					Constant	-1.437	(2.2)
		●				Constant	-2.486	(4.5)
			●			Constant	1.703	(1.6)
				●		Constant	-3.149	(7.9)
		●				LnPHH	1.8340	(11.1)
			●			Veh/HH	-0.7475	(3.6)
	●					LnIncome	0.2305	(2.5)
				●		Income	-8.8820E-03	(1.7)
●	●	●	●	●		IVTT	-0.02745	(3.4)
●	●	●	●		●	OVTT	-0.06806	(11.9)
●	●	●	●			LnCost	-1.1600	(4.9)
			●			Corej	0.9694	(1.7)
			●			LnAreaDeni	0.3217	(1.9)
				●		Stanfordj	2.2090	(2.9)
	●	●	●			Theta (Group)	0.6271	(3.2)
Value of Time (IVTT/Cost * .60 * 55.33)							**$0.78**	
Ratio of OVTT/IVTT							**2.48**	

Note: Variable definitions are included in Table A.1.

Table 5.4
Final Nested Non-Home-Based Mode Choice Model
Nested Model #14W-2

Utility					Variable	NestModel #14W-2	
VD	VP	Trans	Bike	Walk	Name	Coeff.	T-Stat
●					Constant	2.2330	(8.2)
	●				Constant	0.5104	(1.9)
		●			Constant	2.0540	(5.5)
			●		Constant	-4.7690	(18.4)
●					AreaDeni	-5.277E-04	(2.7)
				●	AreaDeni	4.173E-04	(1.8)
●	●	●	●		IVTT	-0.03232	(4.6)
		●			Wait	-0.07836	(6.1)
●	●	●		●	Walk	-0.07583	(19.5)
●	●	●			LnCost	-0.9862	(12.8)
●	●	●			Theta (Motor)	0.9144	(1.0)
Value of Time (IVTT/Cost * .60 * 54.92)						**$1.08**	
Ratio of Wait/IVTT						**2.42**	
Ratio of Walk/IVTT						**2.35**	

Note: Variable definitions are included in Table A.1.

Table 5.5
Final Home-Based School (Grade School) Mode Choice Model
Multinomial Logit Model #21W

Utility				Variable	Model #21W	
VP	Trans	Bike	Walk	Name	Coeff.	T-Stat
●				Constant	2.6250	(5.3)
	●			Constant	7.3003	(7.4)
		●		Constant	-3.1550	(9.3)
	●		●	PHH^3	0.004436	(5.4)
	●			Rurali	1.5440	(3.3)
●				Income (000s)	0.009757	(3.3)
●	●	●		IVTT	-0.05855	(4.1)
●	●		●	OVTT	-0.06384	(10.7)
●	●			LnCost	-1.93000	(8.7)
Value of Time (IVTT/Cost * .60 * 19.57)					**$0.36**	
Ratio of OVTT/IVTT					**1.09**	

Note: Variable definitions are included in Table A.1.

Table 5.6
Final Nested Home-Based School (High School) Mode Choice Model
Nested Model #18W-3

Utility					Variable	Nested Model #18W-3	
VD	VP	Trans	Bike	Walk	Name	Coeff.	T-Stat
●					Constant	-0.6729	(1.0)
	●				Constant	0.1929	(0.2)
		●			Constant	2.9550	(2.8)
			●		Constant	-3.5240	(5.5)
●					Veh/HH	3.5580	(2.0)
	●				Veh/HH	0.5994	(3.5)
●					Pers/HH	-1.5000	(1.6)
		●			Net ResDensI	0.1442	(3.5)
●	●	●	●		IVTT	-0.03228	(1.7)
●	●	●		●	OVTT	-0.03463	(5.9)
●	●	●			LnCost	-2.0340	(5.6)
	●	●			Theta (Group)	0.2583	(5.5)
Value of Time (IVTT/Cost * .60 * 23.9)						**$0.23**	
Ratio of OVTT/IVTT						**1.07**	

Note: Variable definitions are included in Table A.1.

Table 5.7
Final Nested Home-Based School (College) Mode Choice Model
Nested Model #28W-2

Utility					Variable	Nested Model #28W-2	
VD	VP	Trans	Bike	Walk	Name	Coeff.	T-Stat
●					Constant	-1.4610	(0.9)
	●				Constant	-5.5060	(3.4)
		●			Constant	-1.4480	(0.7)
			●		Constant	-3.3980	(4.7)
●	●				Veh/HH	0.7718	(4.6)
●					Pers/HH	-0.2638	(3.0)
●					Ln Net ResDensI	-0.3973	(2.1)
			●		Stanfordi	3.216	(3.1)
			●		PaloAltoi	2.668	(2.8)
			●		Berkeleyi	1.711	(2.5)
			●		Bike Time	-0.07129	(2.6)
				●	Walk (Only) Time	-0.09188	(6.2)
●	●	●			IVTT	-0.02731	(1.1)
●	●	●			OVTT	-0.03923	(2.0)
●	●	●			LnCost	-0.6920	(1.8)
●	●	●			Theta (Motor)	0.5302	(2.6)
Value of Time (IVTT/Cost * .60 * 28.1)						**$0.67**	
Ratio of OVTT/IVTT						**1.44**	

Note: Variable definitions are included in Table A.1.

E. Departure Time Choice Model

Departure time choice, or time-of-day choice models, are very new to metropolitan transportation practice. Some work on time-of-day choice models was completed in Phoenix, Arizona, though this effort assumed a fixed share of home-to-work trips occurring in a three-hour AM peak period. There is also a fairly rich research literature on time-of-day choice models, though this research literature is aimed at understanding travel behavior as opposed to creating a practical model for a practical travel forecasting system.

The departure time choice model included in the BAYCAST model system is a simple, binomial logit choice model with two alternatives:

- leave from home-to-work between 0630 and 0830 AM (peak);
- leave from home-to-work before 0630 or after 0830 AM (off-peak).

The model is applied only to home-to-work auto person trips. The model is applied separately for drive alone, shared ride 2 and share ride 3+ person trips. The share of home-to-work trips of total daily home-based work trips is based on data from the 1990 MTC household travel survey. This data shows that 53.2 percent of daily HBW drive alone trips are in the home-to-work direction; and 56.3 percent of daily HBW share ride 2+ trips are in the home-to-work direction.

The coefficients for the final departure time choice model, model #19W, are in Table 6.

The utility for the off-peak alternative is defined as 0.0. Therefore, the exponentiated utility of the off-peak alternative (exp(0)) is 1.0. In application, the probability of a home-to-work auto person trip starting in the peak period is calculated as:

Probability(Peak Start) = exp(Utility(Peak)) / [1 + exp(Utility(Peak))]

The departure time choice model includes data from the peak and off-peak highway travel time, distance and toll matrices, and data from the zonal demographic file related to the jobs in the retail industry at place of work.

Detailed writeup on this departure time choice model is included in a 12/5/96 memo by C. Purvis in the Technical Memorandum Compilation Volume V.

Table 6
Final Home-to-Work Departure Time Choice Model
Binomial Logit Model #18W and Model #19W

Peak Utility	Variable Name	Model #18W Coeff.	Model #18W T-Stat	Model #19W Coeff.	Model #19W T-Stat
●	Constant	-0.2877	(5.8)	-0.1309	(9.5)
●	CTFT	-0.05540	(3.0)	-0.05556	(3.0)
●	SR Dummy	0.2946	(2.7)	0.2953	(2.7)
●	Auto Distance	5.153E-02	(4.6)	5.254E-02	(4.7)
●	Auto Distance^2	-8.366E-04	(3.7)	-8.464E-04	(3.8)
●	Bridge Dummy	-0.3912	(2.0)	-0.387	(1.9)
●	HH Income	0.000002861	(1.9)		
●	SFOBB WB	-0.6447	(1.8)	-0.6496	(1.8)
●	Retail Industry	-0.3421	(2.0)	-0.3515	(2.1)
Log Likelihood		**-1391.6**		**-1393.5**	

Utility(Off-Peak) = 0
Utility(Peak) = constant + beta01 * CTFT . . . etc.

CTFT = Congested Time Less Free-Flow Time

Log Likelihood Ratio Test: 95% chance that Model #18W is statistically significantly better than Model #19W, 2*(1393.5-1391.6) = 3.8, at 1 degrees of freedom.

Note: Variable definitions are included in Table A.1.

VII. References

1. Planning Section. San Francisco Bay Area 1990 Travel Model Development Project: Compilation of Technical Memorandum Volume I. Metropolitan Transportation Commission, Oakland, California, March 1995.

2. Planning Section. San Francisco Bay Area 1990 Travel Model Development Project: Compilation of Technical Memorandum Volume II. Metropolitan Transportation Commission, Oakland, California, June 1995.

3. Planning Section. San Francisco Bay Area 1990 Travel Model Development Project: Compilation of Technical Memorandum Volume III. Metropolitan Transportation Commission, Oakland, California, March 1996.

4. Planning Section. San Francisco Bay Area 1990 Travel Model Development Project: Compilation of Technical Memorandum Volume IV. Metropolitan Transportation Commission, Oakland, California, June 1996.

5. Planning Section. San Francisco Bay Area 1990 Travel Model Development Project: Compilation of Technical Memorandum Volume V. Metropolitan Transportation Commission, Oakland, California, December 1996.

6. Planning Section. San Francisco Bay Area 1990 Travel Model Development Project: Compilation of Technical Memorandum Volume VI. Metropolitan Transportation Commission, Oakland, California, April 1997.

7. Purvis, Charles L. San Francisco Bay Area 1990 Regional Travel Characteristics: Working Paper #4: 1990 MTC Travel Survey Metropolitan Transportation Commission, Oakland, California, December 1994.

Table A.1
Detailed Definition of Variables used in BAYCAST Travel Demand Models
(in alphabetical sort order)

Variable Name	Model(s)	Definition
AreaDeni	NHBMC	Area Density, zone of production, ((TOTPOP + 2.5 * TOTEMP) / (CIACRE + RESACRE))
Auto Distance	HBWDT	Door-to-Door Drive Alone Peak Period Distance, in miles
Auto Distance^2	HBWDT	Door-to-Door Drive Alone Peak Period Distance, in miles, squared
Berkeleyi	HBCOLM	Berkeley zones, zone of production (zones=718-722, 725-738, 741-747)
Berkeleyj	multiple	Berkeley zones, zone of attraction (zones=718-722, 725-738, 741-747)
Bike Time	HBCOLM	Bicycle travel time, in minutes
Bridge Dummy	HBWDT	Bridge crossing dummy variable (if Drive Alone Toll > 0.0, then Dummy=1)
CIACRE	multiple	Commercial + Industrial Acres (ABAG Land Use)
Constant	multiple	Modal or Utility intercept.
Corej	multiple	Core zone of work (see Table A.2 for definition of CORE)
Cost	multiple	Trip Cost in 1990 cents (per person)
CTFT	HBWDT	Congested Time less Free-Flow Time, in minutes
GPOPD-Leg 1	WHHAO	Gross Population Density (TOTPOP/TOTACRE), MIN(10.0,GPOPD)
GPOPD-Leg 2	WHHAO	Gross Population Density (TOTPOP/TOTACRE), MAX(0,MIN((GPOPD-10.0),20.0))
GPOPD-Leg 3	WHHAO	Gross Population Density (TOTPOP/TOTACRE), MAX(GPOPD-30.0)
HH Income	HBWDT	Household Income in 1989 constant dollars (not divided by 1000)
HH Size	WHHAO	Persons per Household (same as Pers/HH)
HHINC	multiple	Income in 1000s of 1989 dollars (same as Income)
Income	HBSRMC	Household Income in 1000s of 1990 dollars.
Income-Leg 1	multiple	Income in 1989 dollars. MIN(Income,25000)
Income-Leg 2	multiple	Income in 1989 dollars. MAX(0,MIN(Income-25000),50000))
IVTT	multiple	In-Vehicle Travel Time
Ln Net ResDensI	HBCOLM	Natural Log of Net Residential Density, zone of residence, Ln(TOTHH/RESACRE)
LnAreaDeni	HBSHMC	Natural Log of Area Density, Zone of Residence (see Table A.2)
LnCost	multiple	Natural Log of Trip Cost in 1990 cents (per person)
LnEmpDi	HBWMC	Natural Log of Gross Employment Density, Zone of Residence, Ln(TOTEMP/TOTACRE)
LnEmpDj	HBWMC	Natural Log of Gross Employment Density, Zone of Work, Ln(TOTEMP/TOTACRE)
LnIncome	HBSRMC	Natural Log of Household Income in 1000s of 1990 dollars.
LnPHH	HBSHMC	Natural Log of Household Size
MFDU	WHHAO	Multi-Family Dwelling Unit Dummy Variable
Multi-Wrkr/HH	HBWMC	Multiple Number of Workers in Household Dummy Variable
Net ResDensI	HBHSM	Net Residential Density, Zone of Residence, (TOTHH/RESACRE)
No VHH	HBWMC	No Vehicle in Household Dummy Variable
OVTT	multiple	Out-of-Vehicle Travel Time
PaloAltoi	HBCOLM	Palo Alto zones, zone of production (zones=234-238, 245-248, 254-258)
PaloAltoj	multiple	Palo Alto zones, zone of attraction (zones=234-238, 245-248, 254-258)
Pers/HH	multiple	Persons per Household (same as PHH)
PHH	multiple	Persons per Household (same as Pers/HH)
PHH^3	HBGSM	Persons per Household, cubed (polynomial transformation)
RESACRE	multiple	Residential Acres (ABAG Land Use)
Retail Industry	HBWDT	Retail Industry worker Dummy Variable
Rurali	HBGSM	Rural zone of residence (see AREATYPE, Table A.2)

Table A.1 (continued)

Detailed Definition of Variables used in BAYCAST Travel Demand Models
(in alphabetical sort order)

Variable Name	Model(s)	Definition
SFOBB WB	HBWDT	Bay Bridge Westbound Dummy Variable (based on origin & destination zones)
SHPOP62+	WHHAO	Share of Population Age 62+
Single VHH	HBWMC	Single Vehicle in Household Dummy Variable
SR Dummy	HBWDT	Shared Ride 2+ choice, dummy variable
Stanfordi	HBCOLM	Stanford zones, zone of production (zones=244, 249-252)
Stanfordj	multiple	Stanford zones, zone of attraction (zones=244, 249-252)
Theta(Group)	multiple	Nesting, or Scaling Parameter for Group submode choice nested logit
Theta(Motor)	multiple	Nesting, or Scaling Parameter for Motorized submode choice nested logit
Theta(Transit)	HBWMC	Nesting, or Scaling Parameter for Transit submode choice nested logit
Time (Total)	HBSHMC	Total Travel Time, in minutes
TOTACRE	multiple	Total Acres (ABAG Land Use)
Veh/HH	multiple	Vehicles Available per Household (same as VHH)
VHH	multiple	Vehicles Available per Household (same as Veh/HH)
Wait	multiple	Transit wait time, in minutes
Walk	multiple	Walk time, in minutes (may include walk-only utility walk time)
Wrkr/HH	HBWMC	Workers in Household (same as WHH)
ZVHH	multiple	Zero-Vehicle Household Dummy Variable (same as Zero VHH)
ZWHH	multiple	Zero-Worker Household Dummy Variable (same as Zero WHH)

Table A.2
Detailed Variable Categories used in BAYCAST Travel Demand Models

Variable Name	Model(s)	Code	Definition
WRKR/JOB10	**HBWA**		**Worker/Job Ratio Decile (EMPRES / TOTEMP)**
		1	< 0.008 EMPRES/TOTEMP
		2	0.008 - 0.051 EMPRES/TOTEMP
		3	0.051 - 0.140 EMPRES/TOTEMP
		4	0.140 - 0.245 EMPRES/TOTEMP
		5	0.245 - 0.423 EMPRES/TOTEMP
		6	0.423 - 0.668 EMPRES/TOTEMP
		7	0.668 - 0.960 EMPRES/TOTEMP
		8	0.960 - 1.472 EMPRES/TOTEMP
		9	1.472 - 2.590 EMPRES/TOTEMP
		10	> 2.590 EMPRES/TOTEMP
GEMPDG10	**HBWA**		**Gross Employment Density, Zone of Work, Decile**
		1	< 1.0 TOTEMP/TOTACRE
		2	1.0 - 2.0 TOTEMP/TOTACRE
		3	2.0 - 4.0 TOTEMP/TOTACRE
		4	4.0 - 6.0 TOTEMP/TOTACRE
		5	6.0 - 8.0 TOTEMP/TOTACRE
		6	8.0 - 12.0 TOTEMP/TOTACRE
		7	12.0 - 18.0 TOTEMP/TOTACRE
		8	18.0 - 30.0 TOTEMP/TOTACRE
		9	30.0 - 70.0 TOTEMP/TOTACRE
		10	> 70.0 TOTEMP/TOTACRE
Area Type	**multiple**		**Area Type, based on Area Density**
			Area Density = ((TOTPOP + 2.5 * TOTEMP) / (CIACRE + RESACRE))
		0	Core (Area Density > 300.0)
		1	Central Business District (Area Density = 100.0 - 300.0)
		2	Outlying Business District (Area Density = 55.0 - 100.0)
		3	Urban (Area Density = 30.0 - 55.0)
		4	Suburban (Area Density = 6.0 - 30.0)
		5	Rural (Area Density < 6.0)
Employment	**multiple**		**Employment Type based on SIC codes (ABAG Database)**
		RETEMP	Retail Trade Employment (SIC = 52-59)
		SEREMP	Service Employment (SIC = 70-89)
		OTHEMP	Other Employment (SIC = 15-17, 40-49, 60-67, 91-97)
		MANEMP	Manufacturing Employment (SIC = 20-39)
		AGREMP	Agricultural & Mining Employment (SIC = 1-14)
		WHTREMP	Wholesale Trade Employment (SIC = 50-51)

Acknowledgments

These travel demand models are the product of many years of effort by staff of the Metropolitan Transportation Commission Planning Section. MTC planners were assisted by computer programming staff from MTC's Technical Services Section, and by the consulting firm of Cambridge Systematics, Inc.

MTC management in support of this model development project include:

- Lawrence D. Dahms, MTC executive director;
- William F. Hein, MTC deputy executive director;
- Chris Brittle, Planning Section Manager; and
- Marilyn M. Reynolds, Technical Services Section Manager.

The transportation analysis unit of the MTC Planning Section were responsible for this model development effort. Staff include:

- Chuck Purvis, Senior Transportation Planner/Analyst;
- Ron West, Associate Transportation Planner/Analyst;
- Miguel Iglesias, Associate Transportation Planner/Analyst;
- Rupinder Singh, Associate Transportation Planner/Analyst; and
- Victoria Eisen, Associate Transportation Planner/Analyst.

Lisa Klein, junior transportation planner, assisted in the development of the regional transit network.

Computer programming support was provided by Pat Hackett, senior analyst in the Technical Services Section.

MTC staff are also indebted to the training and assistance provided by Mr. Earl Ruiter and Dr. Yoram Shiftan of Cambridge Systematics, Inc. Their training of MTC staff in the art and science of discrete choice model development was critical to the overall success of this major project.

The Model Coordination Working Group of the Bay Area Partnership provides peer review support, advice and critique for travel model development activities in the Bay Area. MTC staff would like to thank the transportation professionals who work on this Working Group for their contributions to this effort.